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THE MODEL 200 PULSE COUNTER

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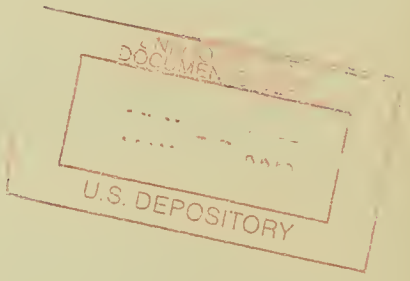

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THE MODEL 200 PULSE COUNTER

By W. A. Higinbotham, James Gallagher, and Matthew Sands

ABSTRACT

A complete general purpose electronic pulse counter is described which consists of an amplitude discriminator, scale-of-64, and register driver, and is suitable for use with pulse amplifiers in making nuclear measurements.

INTRODUCTION

For the work of the Los Alamos Laboratory a large number of pulse counters were needed. It was desirable, therefore, that a counter be available which could be used in many different applications, which would be quite reliable, and which could be manufactured easily. The counter to be described was designed to fit these requirements.

The Model 200 Pulse Counter is used for counting (after amplification) the individual pulses from an electrical detector of high-energy particles, i.e., an ionization chamber, proportional counter, or Geiger-Mueller tube.

The information contained in the signal of an electrical ionization detector consists, at least in part, of the distribution of amplitudes of the pulses under fixed experimental conditions, or of the variation of the rate of occurrence of pulses with a given magnitude with changes in the experimental setup. The counter is suitable for extracting such information from the amplified electrical signals of a detector.

DISCUSSION

The counter to be described consists of three principal parts: (1) an amplitude discriminator which selects for counting only those pulses at its input whose amplitude is greater than some chosen magnitude; (2) an electronic tallying circuit or scaler which provides one output pulse for each 64 pulses which it receives; (3) a circuit which operates an electromechanical counter, or register, each time the scaler produces an output pulse. Each of these component parts will be discussed in detail.

The Amplitude Discriminator

The amplitude discriminator of the Model 200 Pulse Counter is a trigger circuit which produces a pulse of standard size whenever it receives a pulse whose amplitude is greater than some predetermined value. The discriminator to be described has the following desirable properties: (1) it can discriminate reliably between pulses which differ in amplitude by a small fraction of one volt; (2) the amplitude at which discrimination occurs is stable to a similar extent; (3) the discrimination voltage is easily adjustable from 10 to 100 volts; (4) it is capable of accepting pulses the duration of which is a few tenths of a microsecond, or greater; (5) it will respond to two pulses separated by intervals as small as 0.5 microsecond; (6) it presents a high impedance to the input signal source. Circuits which in practice have been found to possess the above properties are modifications of the Schmitt trigger circuit.[1]

[1] O. H. Schmitt, Jour. Sci. Inst. 15, 24 (1938). See O. S. Puckle also for a discussion of the basic Schmitt circuit, Time Bases, John Wiley & Sons, New York, 1943.

The particular modification of the Schmitt trigger circuit used in the Model 200 Counter is shown in Figure 1. It is based on two pentodes, since this allows increased speed and greater stability of operation. The operation of the circuit is such that the steady potential at the output lead can take either of two values, depending on the instantaneous potential at the grid of T-1. The components and the supply potential have been chosen such that if the potential at the grid of T-1 is less than about +105 volts with respect to ground, the tube T-2 will be conducting and the tube T-1 will be cut off. Under these conditions the output signal lead is at +265 volts. If the grid of T-1 is above +105 volts, tube T-1 will be conducting, T-2 will be cut off, and the potential of the output signal lead will be +300 volts. The transition from the first state to the second takes place rapidly and irreversibly when the input grid potential reaches some well-defined "triggering" voltage in the vicinity of +105 volts. The value can be made exactly 105 volts by adjustment of the resistor R_6. The constancy to which this value is maintained depends on the stability of the +300 volt supply, on the stability of the resistances R_3, R_4, and R_8, and on the variations in the cathode emission and contact potentials in the tubes. Because of the symmetry of the circuit these latter effects are minimized. For variations of $\pm$ 10% in the heater supply voltage and for normal tube variations, over a period of months the triggering voltage seems to remain stable to about 0.2 volts.

When the input-grid potential is decreasing from values above +105 volts, triggering to the initial state occurs at some value slightly below that at which the initial triggering took place. The difference in the two triggering potentials is called the hysteresis of the discriminator. The hysteresis is determined mainly by the value of the resistance in the plate circuit of T-1. For the components of Figure 1, the hysteresis is about 3 volts, which seems to be a good compromise for a general purpose instrument. If the hysteresis is made zero, there will be a tendency for the circuit to oscillate when the grid is near the triggering potential because of the action of C_1. Such a condition should be avoided, since the discriminator may then produce several output pulses in response to one slow input signal.

Operation of the discriminator for slow signals is illustrated in the cyclograms which are given in Figure 2. In all the photographs the sweep voltage is a 2500-cycle per second sine wave of 20 volts peak-to-peak amplitude (positive to the right), which is also fed to the input of the discriminator. Figure 2-A shows the signal at the output of the discriminator. It can be determined from this figure that this particular discriminator has a hysteresis of 4 volts and that a bias setting of 2 volts was used. The vertical height of the oscillogram 2-A is 35 volts. In Figure 2-B and 2-C the vertical deflection sensitivity and horizontal sweep are the same as for Figure 2-A. In B the potential of the plate of T-1 is shown and in C the common cathode potential. The operation of the discriminator in response to pulses may be deduced from the previous discussion.

As indicated in Figure 1, the signals are introduced into the discriminator by means of a blocking capacitor and a resistor network for biasing. If the bias potential of the input grid is set by means of R_9 at, say +85 volts, any signal less than 20 volts in amplitude will fail to bring the input grid to +105 volts, and will not trigger the discriminator. If, however, a positive signal of amplitude greater than 20 volts is introduced, the discriminator will be triggered to the other state and will remain there as long as the instantaneous signal potential is greater than 20 volts. (The duration of the output signal will depend on the amplitude and duration of the input signal.) If the bias potential of the input grid is now set to some value greater or less than 85 volts, the amplitude of input signals which will trigger the discriminator will be decreased or increased in that order. The bias setting of the discriminator, or the signal amplitude which is just sufficient to effect the triggering action, is the difference between the triggering potential (+105 volts) and the bias potentiao of the input grid. The bias setting of the discriminator can be made any value between zero and 100 volts by means of R . If the dial of R_9 is graduated from zero to 100 over 270°, it can be made to read directly the bias setting. This is effected by setting the rheostat R_7 until a rotation of 270° of R_9 gives a potential change of 100 volts at the input grid and then setting the dial on the shaft of R_9 so that the indicator is at zero when the potential is +105 volts with respect to ground. Bias settings less than the hysteresis cannot in general be used. For the sake of stability the resistors R_3, R_4, R_8, R_7, R_8 and R_9 are usually made wire wound. Since R_1, R_2 and R_5 do not directly determine the triggering potential, composition or metallized resistors are used. If some sacrifice in long time stability can be made and if the direct

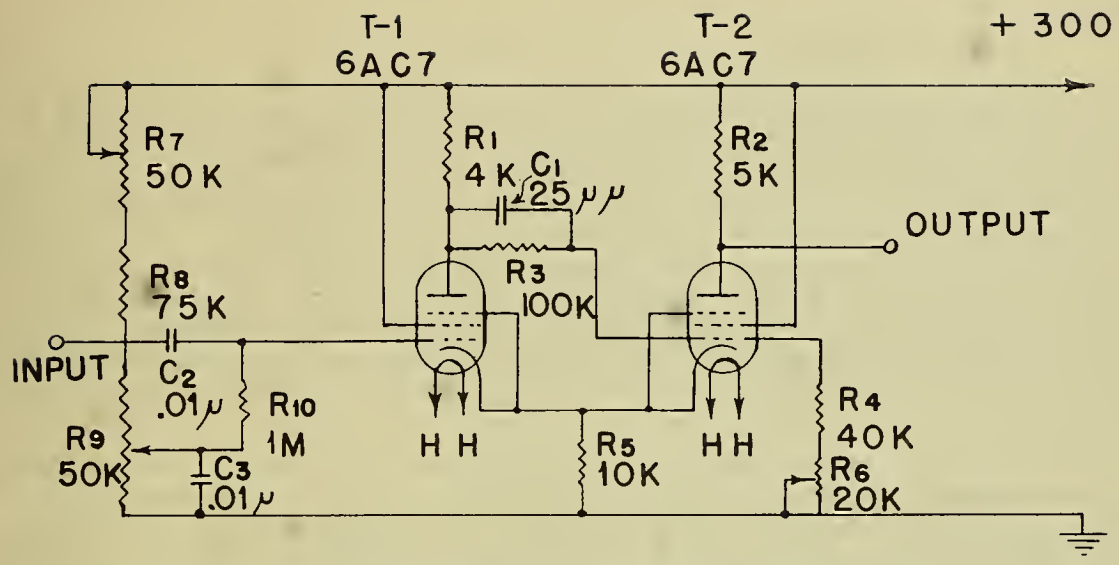

Figure 1. Circuit diagram of the amplitude discriminator.

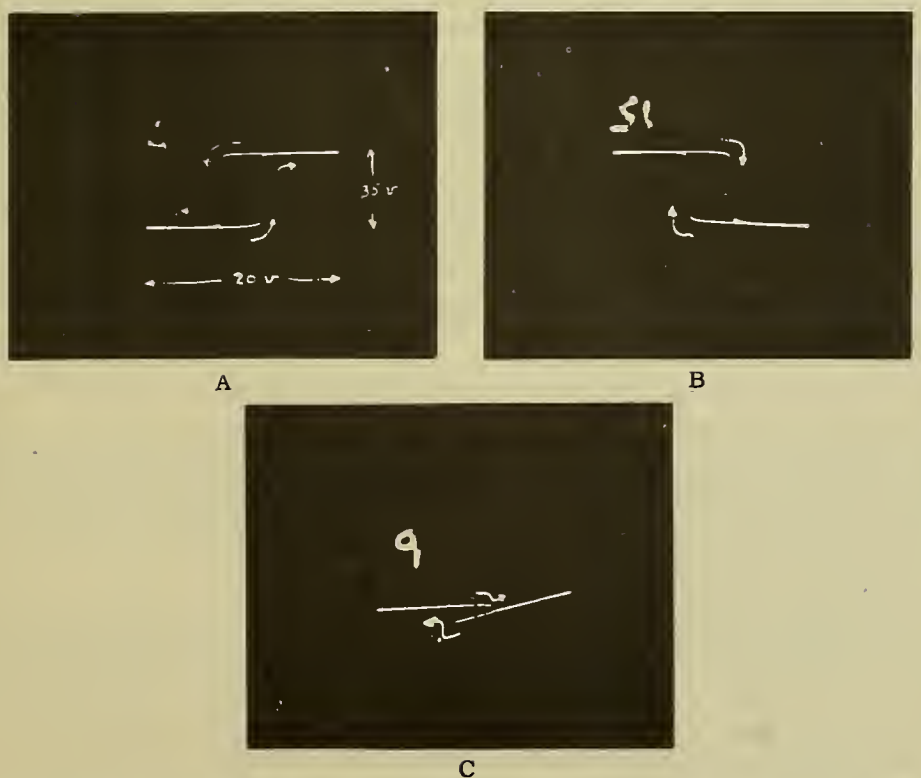

Figure 2. Cyclograms of the discriminator operation. The time base is a 2500-cps sine wave with a peak-to-peak amplitude of 20 volts.

A. Waveform appearing at the plate of tube T-1.
B. Waveform appearing at the plate of tube T-2.
C. Waveform appearing at the common cathode.

reading bias dial is not desired, an appreciable economy is effected by omitting R_6 and R_7 and by using carbon resistors throughout.

For a large input pulse having a small rise time, the rise time of the output pulse depends only on the resistance R_2 and the parasitic capacitance shunting it. For fast pulses that just trigger the discriminator and for slow input signals, the time of rise of the output pulse is slightly greater. Some decrease in the rise time of the output signal can be achieved by applying shunt compensation to the plate circuits of both tubes. It should be noted that the output signal may never reach its full value if the input signal does not remain above the bias voltage for a sufficient length of time. For this reason it is desirable that narrow input pulses should either be rectangular in shape or at least have a sufficiently long flat top. With the present circuit only pulses of duration greater than 0.1 microsecond are counted. The capacitor C_1 should ideally be chosen to obtain a frequency independent voltage divider from the plate of T-1 to the grid of T-2. The value given in Figure 1 is actually larger than would be required according to the above criterion, but seems to be more suitable in a general purpose instrument.

The maximum permissible duration of the input pulses is determined solely by the time constant of the input coupling network. If slow pulses which are not large compared with noise are being counted, it is possible for the discriminator to respond to each of several noise waves on the rise or fall of the pulse, giving many counts for each pulse. This can be avoided either by making the hysteresis at least as large as the noise or by making the resolving time of the conjoining circuit slightly greater than the duration of a single pulse.

Since it is often necessary to count small pulses in the presence of much larger ones, it is important that the discriminator not overload easily. The grid of the tube T-1 is normally well below its cathode potential. Once the triggering voltage has been exceeded, however, T-1 acts as a cathode follower and continues to present a high impedance to the signal source. For the circuit values shown in Figure 1, the tube T-1 does not draw grid current on slow signals until its grid potential reaches about +200 volts with respect to ground. Thus if a bias setting of a few volts is used, the circuit will not overload for pulses of 100 volts amplitude. If the input pulses have a rise time of less than 0.1 microsecond and if the capacitance to ground of the cathode lead is unduly large, grid current will be drawn for somewhat smaller signals. Grid current should be avoided, since it alters the charge on the input capacitor and results in a temporary shift of the bias setting of the discriminator. Although it might appear desirable to make the input time constant short, to allow a speedy recovery in such cases, other considerations demand that the time constant be large.[2] The value 0.01 second seems to be a reasonable compromise.

The Scaler

Since it is often either desirable or necessary to take data at a more or less rapid counting rate, it is convenient to circumvent the limitations of mechanical registers by the use of scaling circuits. The Model 200 Counter was developed primarily for counting pulses which are distributed randomly in time, although it has been used for counting pulses the occurrence of which was neither regular nor random, according to the usual definitions.

Although a quantitative discussion of the errors introduced by practical apparatus when used for counting random events will be found in the literature,[3] a few remarks may be in order. Any counting circuit possesses a dead time T (usually referred to as the resolving time of the counting circuit) following each pulse it records, during which time it is incapable of recording another pulse. If the arrival of pulses to the counter is perfectly random, and the pulses occur at an average rate of n per second, then the fractional counting loss due to the dead time of the counting circuit is nT, so long as $nT \ll 1$. It is apparent that if one wishes to count random pulses occurring, for instance, at an average rate of 1000 per second, with only one per cent counting loss, the resolving time of the counter must

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[2] This time constant is essentially one of the coupling elements of the preceding pulse amplifier.

[3] W. B. Lewis, Electrical Counting, Camb. Univ. Press, 1943.

be 10 microseconds. A resolving time of 10 microseconds, however, does not necessarily require that the counter be capable of handling 10^5 regularly spaced pulses per second.

It is true that a single resolving time completely characterizes a counting circuit only if the counter comprises a long chain of identical scaling elements, or if the resolving time of each element in the chain is just sufficient for it to pass along the pulses which it receives when pulses are entering the chain at the maximum regular rate of $1/T_1$, where T_1 is the resolving time of the first scaling element. In a practical counting circuit, it is not convenient or economical to meet this requirement in a strict sense. An electronic scaling circuit is terminated ordinarily by an electromechanical register which can record 10^4 or more impulses but whose resolving time may lie in the range 0.1 to 0.01 second. It would be necessary to precede the register by a scale-of-10^4, if a counter with an ideal resolving time of 10 microseconds were to be achieved. Since it can be shown that when randomly occurring pulses are being counted, a considerable "smoothing" effect exists after the counting rate has been reduced by a large scaling factor, it is unnecessary to have the ideal resolving time. A scale-of-64 seems to be sufficient for most cases, although a number of scales-of-256 and greater have been used.

The Model 200 Counter contains a scale-of-64, consisting of six scaling stages, each of which is a scale-of-2. The counter is usually used in connection with a register whose resolving time is 0.02 second. The resolving time of the first scaler is 5 microseconds, and the resolving time of the successive stages is such as to meet the ideal requirement given above. The resolving time of the register does not meet the ideal requirement, but, because of the smoothing effect mentioned, the counter can be used to count random pulses at an average rate of 10^5 per minute with less than one per cent counting loss.

The scale-of-2 employed in the counter seems to be superior to any yet suggested. It requires no adjustment but operates with complete reliability. It is simple and economical to construct, and the checking and servicing can be done by an average technician, since failures are usually due to initially defective parts or wiring. The circuit was developed in 1943 by one of the authors, W. A. Higinbotham.

Since more than a thousand scales-of-2 have been used at Los Alamos, it was found convenient to construct each scale-of-2 as a plug-in unit. The type of construction employed is illustrated in Figure 3. Since it is not necessary that all six units constituting the scale-of-64 be identical to maintain an ideal resolving time throughout the scaler, two different types of unit are used. The basic circuit for both types is shown in Figure 4. Suitable values for the circuit components are indicated in the caption for the figure.[4] The first two scale-of-2 units in the Model 200 Counter are 6SN7 units and have a resolving time of 5 microseconds.[5] These are followed by four 6SL7 units, which have a resolving time of 20 microseconds. Both units are constructed in much the same way and have all necessary connections brought out to the pins of an octal plug. Since the 6SL7 units dissipate one-half as much power and require one-fourth as much current from the positive supply source, it is economical to use them in applications where the shorter resolving time of the 6SN7 units is not needed. The operation of the two units is quite similar; only the 6SN7 unit will be discussed in detail.

The scale-of-2 circuit, shown in Figure 4, is based on the well-known Eccles-Jordan trigger circuit[6] (called here a "flip-flop") which is here symmetrically coupled to a single source of triggering by means of two diodes. The circuit is capable of being triggered alternately from one state

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[4] Recently germanium crystal diodes have been found to work quite satisfactorily as coupling elements in the scale-of-2. Two Sylvania-type 1N34 diodes in series are used to replace each half of the 6H6.

[5] The 6SN7 scaler built with the same components but not with plug-in type construction will usually having a resolving time of about two microseconds.

[6] For operation and theory of the Eccles-Jordan trigger circuit, see H. J. Reich, Theory and Applications of Electron Tubes, 2d ed, McGraw-Hill Book Company, New York, 1944.

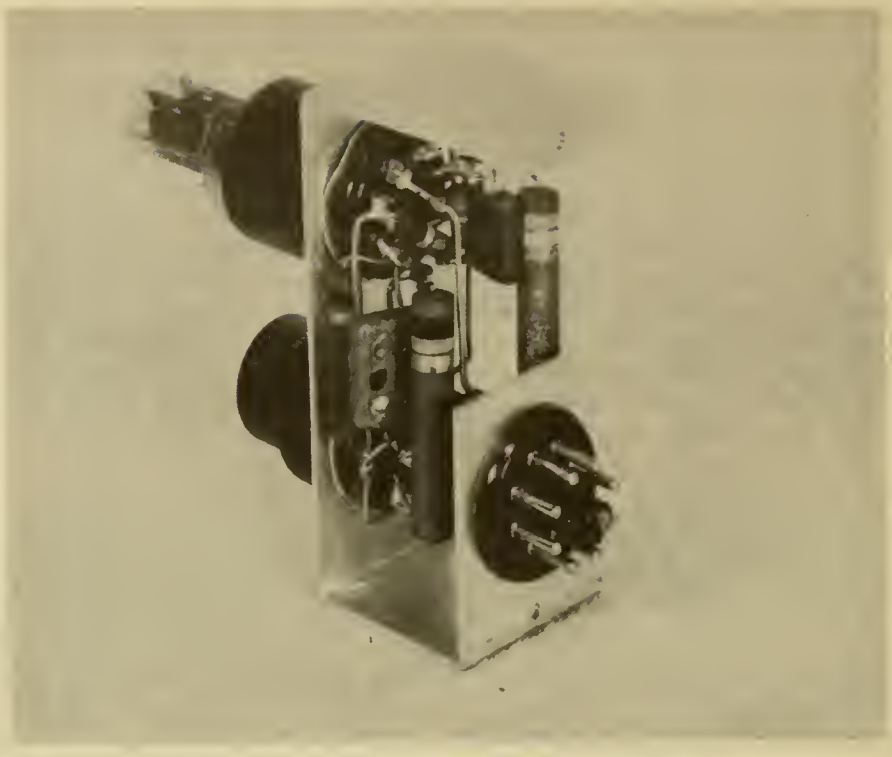

Figure 3. Photograph of the plug-in scale-of-2.

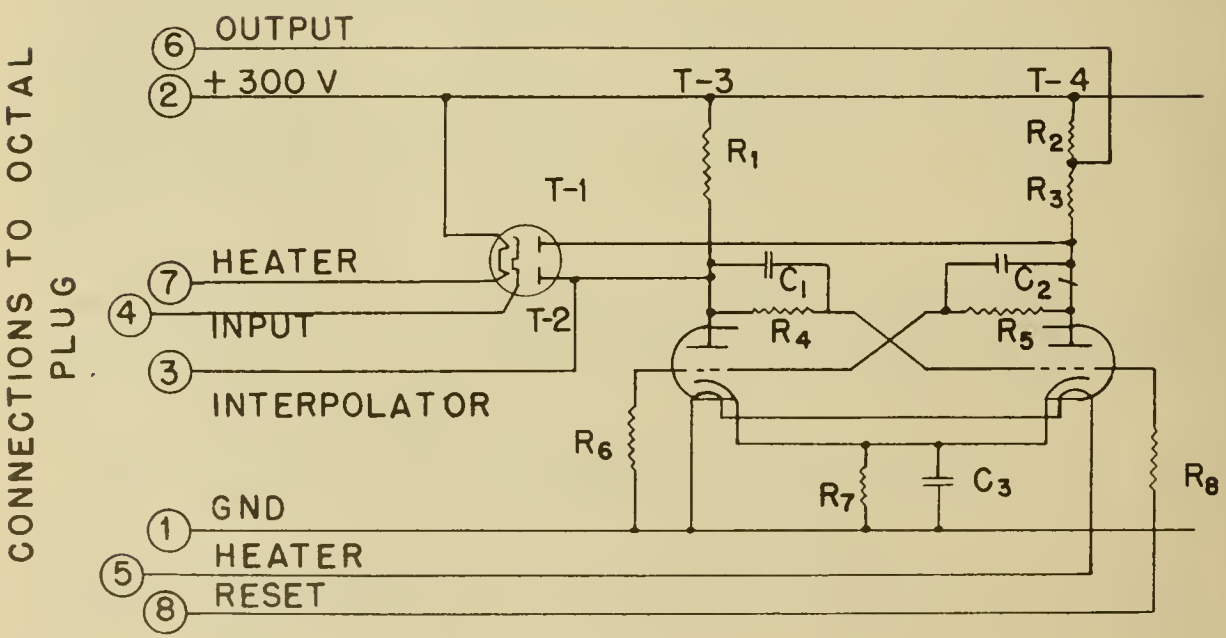

Figure 4. Basic circuit of the scale-of-2. For 6SN7 unit: T-2—6H6; T-3 and T-4—6SN7; R_1—20k; R_2—5k; R_3—15k; R_4 and R_5—200k; R_6 and R_8—100k; R_7—10k; C_1 and C_2—50 $\mu\mu$f; C_3—0.01. For 6SL7 unit: T-1 and T-2—6H6; T-3 and T-4—6SL7; R_1—100k; R_2—25k; R_3—75k; R_4 and R_5—200k; R_6 and R_8—500k; R_7—40k; C_1 and C_2—40 $\mu\mu$f; C_3—0.01.

to the other by successive, identical, negative triggers. The essential properties of the circuit, in addition to those inherent in the flip-flop, concern the switching mechanism by which the effect of the trigger is different on the two halves of the circuit, depending upon which half is conducting, and the choice of operating conditions which give a large measure of stability. The use of diodes to accomplish a unilateral switching action in the manner indicated in Figure 4 is believed to be new.[7] In normal operation the "reset" lead is externally connected to ground, and the "interpolator" lead goes to a high-impedance indicator.

If the input signal lead has a steady potential of +300 volts, neither of the diodes will be conducting, since the potential of the plates of both diodes is less than their common cathode potential. Let us assume that the state of the flip-flop is such that tube T-4 is at first conducting. Its plate will then be at +150 volts, its cathode at +80 volts, and its grid will be held at +82 volts by virtue of grid current flow. The plate of T-3 will be at +280 volts and the grid of T-3 at +50 volts, thereby cutting off the tube. If the input voltage is slowly decreased, the diode T-2 begins to conduct. Since its resistance is small compared with the resistance R_1, the plate of T-3 follows the signal. The grid of T-4 does not move in the manner which might at first be expected, but drops only slightly in potential so long as grid current is being drawn. A decrease in the grid current takes up the decrease in voltage across R_4 until the input signal reaches 240 volts. It will be noticed that, when the input signal is held fixed at either +300 or at +250 volts, the flip-flop can exist quite stably in either of its two possible states. Also, as long as one of the tubes is drawing grid current, the circuit has no tendency to be triggered by small fluctuations at the input signal lead. In fact, when the input signal lead was at +250 volts, in the above discussion, a small variation at that point appears as a much smaller signal at the output lead. This fact is of importance, since part of the simplicity of this circuit lies in the possibility of connecting an indefinite number of such circuits directly together with no resulting instability.[8] The self-biasing arrangement in the catnode circuit of T-3 and T-4 adds greatly to the stability of the flip-flop.

Let us suppose now that the input signal voltage is brought suddenly from +300 volts to +250 volts. The potential of the grid of the conducting tube T-4 immediately goes negatively by about 30 volts, an amount which is determined by the ratio of C_1 to the static parasitic capacitance at the grid of T-4. Immediately following the input signal, the plate potential of T-4 starts to rise rapidly, and the grid of T-3 moves positively a proportionate amount determined by the ratio of C_2 to the parasitic capacitance at the grid. The tube T-3 begins to conduct, and regeneration causes the circuit to proceed toward its other equilibrium state. Before the state equivalent to the original state is reached, however, the plate of T-4 is "caught" by the diode T-1 and the circuit assumes a stable state with the plate of T-4 at +250 volts. If now the input voltage is returned either quickly or slowly to +300 volts, there is no effect on the trigger circuit other than causing it to assume the stable state which is the exact mirror image of the original state described. The application of a second trigger similar to the first causes the circuit to pass through a similar cycle of operations in which the role of T-3 is now replaced by that of T-4, and vice versa.

It should be noticed that the diodes provide a switching action, in that on application of the triggering signal a potential change is transmitted to only one grid, and that no signal appears at the opposite grid to counteract the effect of the trigger. Also, as soon as the triggering action has begun, the negatively moving plate "disconnects" itself from the input lead and the flip-over process proceeds unhampered. Because of this, triggering can be effected by a short signal (as is done in the first stage of the counter) or by a rectangular signal (as is done when a stage is triggered by the preceding one). The reliability of the circuit rests in the switching action of the diodes. The capacitive portion of the couplings employed in the flip-flop not only allows rapid operation of the circuit but is

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[7] Subsequent to the development of the circuit shown here, it was pointed out to the authors that scales-of-2 using metallic rectifiers are described by W. B. Lewis (op. cit.). The mechanism of operation, however, is somewhat different.

[8] As many as twenty stages have been used in one continuous chain.

an essential part of the triggering mechanism as described. The output connection of the scale-of-2 alternates in potential between +300 and +250 volts during the operation. This signal has the correct d-c level and the correct amplitude for triggering the next scale-of-2 unit to which it is direct-coupled (to pin 4). Evidently any number n of the scale-of-2 units can be direct-coupled in a chain to form a scale-of-2^n. The use of diodes as automatic switching devices, as shown here, is also very useful in many other types of circuit.[9]

Since a finite time is required for the flip-over action, and since an additional recovery time must elapse after flip-over before static conditions again prevail, the scale-of-2 circuit will respond to a second input signal only after a certain time has elapsed following a previous signal. The resolving times given above were achieved by striking a compromise between these two effects and the required reliability of the circuit. Similar scales-of-2 with varying degrees of reliability have been made, with resolving times down to 0.2 microsecond.

Pulse forms which appear in a chain of scaling units are shown in Figure 5. In all the photographs the vertical scale is the same (positive upwards) and in all but F the same linear horizontal sweep was used. Double positive pulses with an amplitude of 50 volts are being fed to the input of the discriminator. The pulses are 5 microseconds apart and are repeated 1000 times a second. In Figure 5-A the input pulses are shown. The signals which appear at the input to the first scaling stage are shown in B, and the output of that stage (input to the second stage) is shown in C. Figure 5-D shows the signal between stages two and three. The signal between stages three and four is shown in E. The same signal is shown in F but here with a total horizontal sweep time of 11 milliseconds.

The interpolation indicator for the scale-of-2 is a 1/25-watt neon lamp connected to the plate of T-3 through a 1-megohm resistor. As soon as T-3 is conducting and its plate potential has dropped to +150 volts, the lamp will fire and carry a current of 100 microamperes. A neon lamp so operated gives sufficient light to serve as an effective indicator for normal visual purposes and has a negligible effect on the operation of the scale-of-2. The interpolation lamps are, of course, not necessary when a large number of counts occur in each observation, but they are useful at slow counting rates and serve as a visual indication of the proper operation of the circuit.

The Register Driving Circuit

Since economy dictates the use of an electromechanical impulse register to terminate a scaling circuit, the final function of a counter circuit is the production of signals for operating a register. Most registers consist of a ratchet-operated mechanism which involves a dial or a wheel counter, indicating one digit for each electrical impulse received. The limiting speed at which a register will record impulses faithfully is dependent on the mechanical inertia of the mechanism and on the amount of power which can be supplied to effect the necessary mechanical motion. Energy is supplied to a register by means of current through a coil which has a large inductance. Evidently the rate at which a register can operate depends in part on the driving voltage, the maximum value of which is limited by the breakdown voltage of the insulation used in the register windings. Also, if the mechanical inertia of the register mechanism is to be the limiting factor in the speed of operation, it is necessary that the resistance of the driving source be high enough that the time constant L/R of the register associated circuit will be short compared with the time for mechanical motion. For this reason the register is best operated in the plate circuit of a pentode and with a plate supply having the highest voltage conveniently available.

Registers are commercially available which have been designed specifically for use with electronic counters. Registers of this type made by the Cyclotron Specialties Company of Moraga, California, are used with the Model 200 Counter. They have a minimum operating current of 10 ma, an inductance of 3.3 henrys and a d-c resistance of 1000 ohms. A register of this type can be operated at continuous counting rates of 50 impulses per second with the circuit shown in Figure 6.

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[9] A diode switching arrangement has been used to convert a scale-of-16 into a decade (scale-of-10) scaler, which operates completely satisfactorily. The scale-of-10 circuit will be described at a later date.

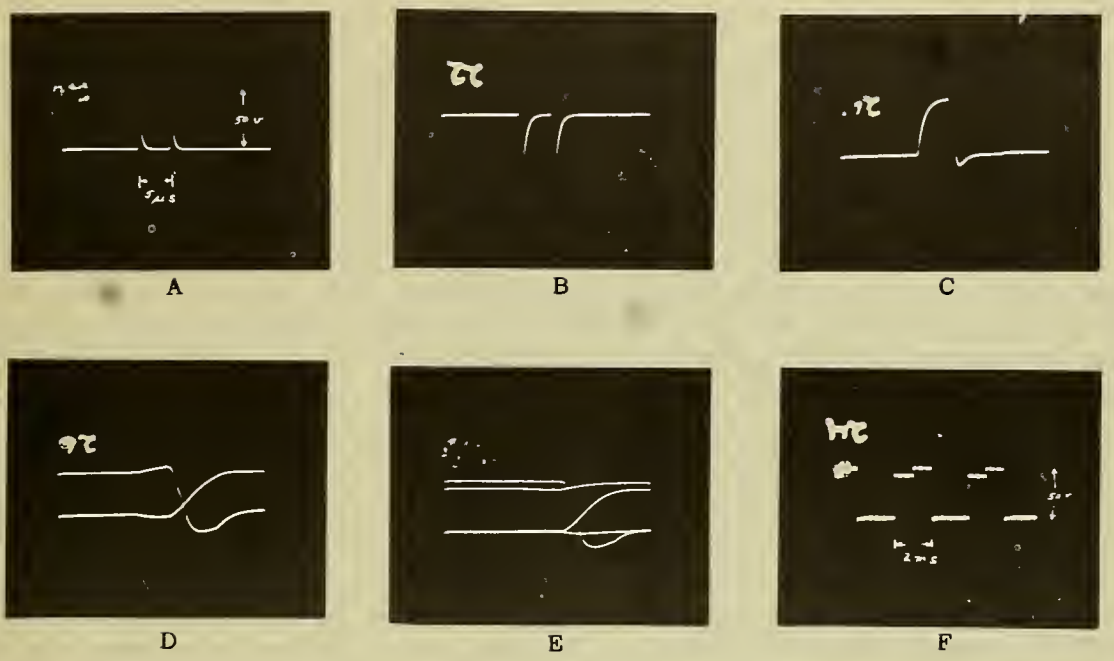

Figure 5. Pulse forms which appear in the pulse counter with a linear time base.

A. Input pulses of 50-volts amplitude separated by 5 microseconds.
B. Input to the first scale-of-2.
C. Output of the first scale-of-2.
D. Output of the second scale-of-2.
E. Output of the third scale-of-2.
F. Output of the third scale-of-2 with the linear time base 11 microseconds in length.

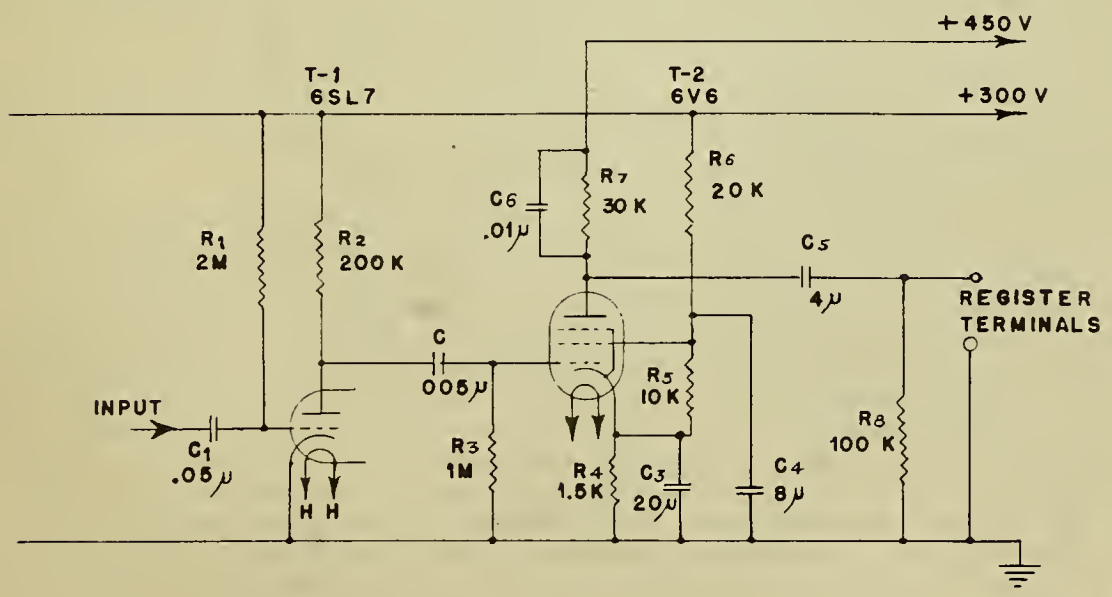

Figure 6. Diagram of the register driving circuit.

The plate voltage for the output stage of the driver circuit is secured from the unstabilized part of the power supply. This arrangement prevents transients, which arise when the register is actuated, from interacting with other parts of the counter and causing spurious counts. The higher supply voltage is also advantageous. The driver stage shown does not load the final scaler stage to such an extent that the scaling operation becomes unreliable. The impedance inserted across the register winding is sufficient to prevent the production of voltage surges large enough to damage the insulation. The circuit operation consists essentially of placing a sufficiently high voltage across the register until it closes, and then of removing this voltage to enable the register to recover in preparation for the next count. If the square voltage pulse is too long, the maximum permissible counting rate is reduced, whereas if it is too short, the register may occasionally miss. In the present circuit the signal which is applied to the grid of the driver tube is a very nearly rectangular, positive voltage pulse of 10 milliseconds duration. This seems to be sufficient for reliable operation of the registers.

The tube T-1 of Figure 6 and its associated components serve as a device for producing the requisite pulse shape. The negative step pulse which appears at the output terminal of the last scaling stage is converted into a triangular pulse at the grid of T-1 by the resistance-capacitance network in the grid and the mechanism of grid current. This triangular wave cuts off the plate current in T-1 for 10 milliseconds. The plate of T-1 would rise to the positive supply potential during this 10 milliseconds were it not that the grid of T-2 will always be driven at least to the cathode potential and held there for the 10 millisecond period of operation of the register. The circuit shown also insures that operation of the register is reliable at rates from the slowest to the maximum permissible (about 50 per second). The register can be put directly in the plate circuit of T-2, but for the safety of personnel, as well as the register insulation, one side of the register is grounded and the operating current is supplied through the blocking capacitor C_5.

This driver circuit can be used for any register which does not require more than 40 milliamperes or 300 volts. For the optimum speed of operation of any register, the time constant in the grid circuit of T-1 should be suitably chosen. The time constant in the grid of T-2 is not critical and need only be sufficiently large.

The Complete Counter

The circuit diagram of the complete Model 200 Counter is given in Figure 7. In addition to the circuit elements already described, it contains a coupling stage between the discriminator and the scaler, a regulated power supply, and an output stage to an external counting rate meter. A photograph of a completed counter containing plug-in units is shown in Figure 8.

In Figure 7, tubes T-1 and T-2 comprise the discriminator. The additional components in the grid circuit permit the input to be connected and disconnected at the beginning and end of a measurement without introducing spurious switching counts at the same time.

The positive signals from the discriminator are converted into sharp pulses, inverted. and amplified by the tube T-3A and its associated components. The 65-volt negative signal thus produced then goes to the first scale-of-2. The wiring diagram to the sockets for plug-in units is shown in the figure. The numbers which appear correspond to those shown in Figure 4. The first two plug-in units are 6SN7 units, the last four, 6SL7 units. The reset leads are connected together and to ground through a normally closed push-button switch. When this switch is opened momentarily, the potential of the reset line rises about 50 volts and returns all the flip-flops to the starting state. The resistor across the switch is necessary to prevent the reset line from going too far positive when the connection to ground is broken. If the reset line goes much more than 50 volts positive, the cathode potential of the flip-flops changes so much that the circuits are momentarily unstable when the switch is closed again, and resetting is not accomplished. The interpolation indicator circuit (neon lamps and 1-megohm resistors) is shown. The lamps are extinguished in the starting position. They are labelled 1, 2, 4, 8, 16, and 32. The sum of the numbers corresponding to the lamps which are lighted shows the number of pulses received after the last multiple of 64. The tube T-3b is a cathode follower which couples the output of the first scaling stage to an external counting rate meter. The signal which

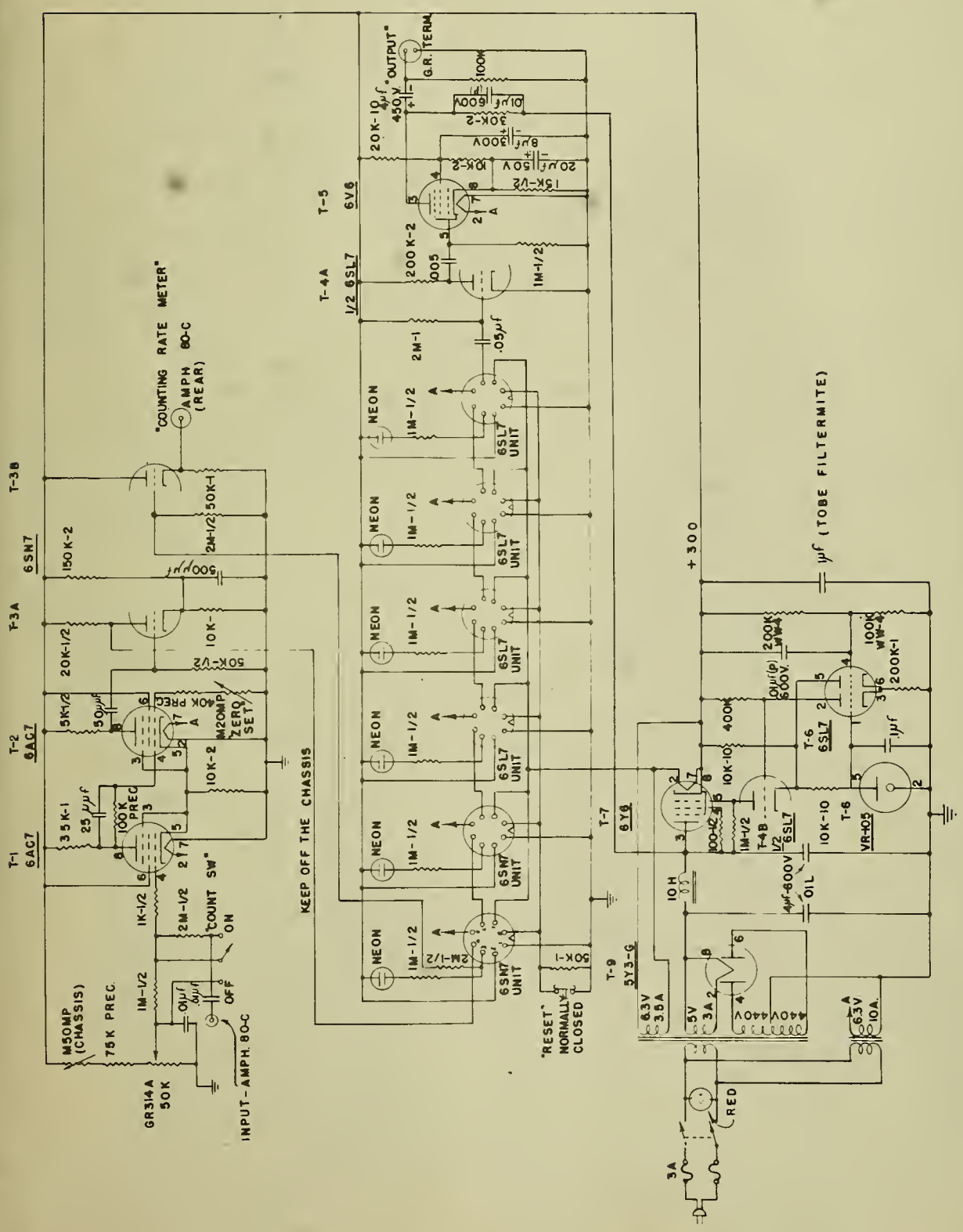

Figure 7. Circuit diagram of the complete pulse counter.

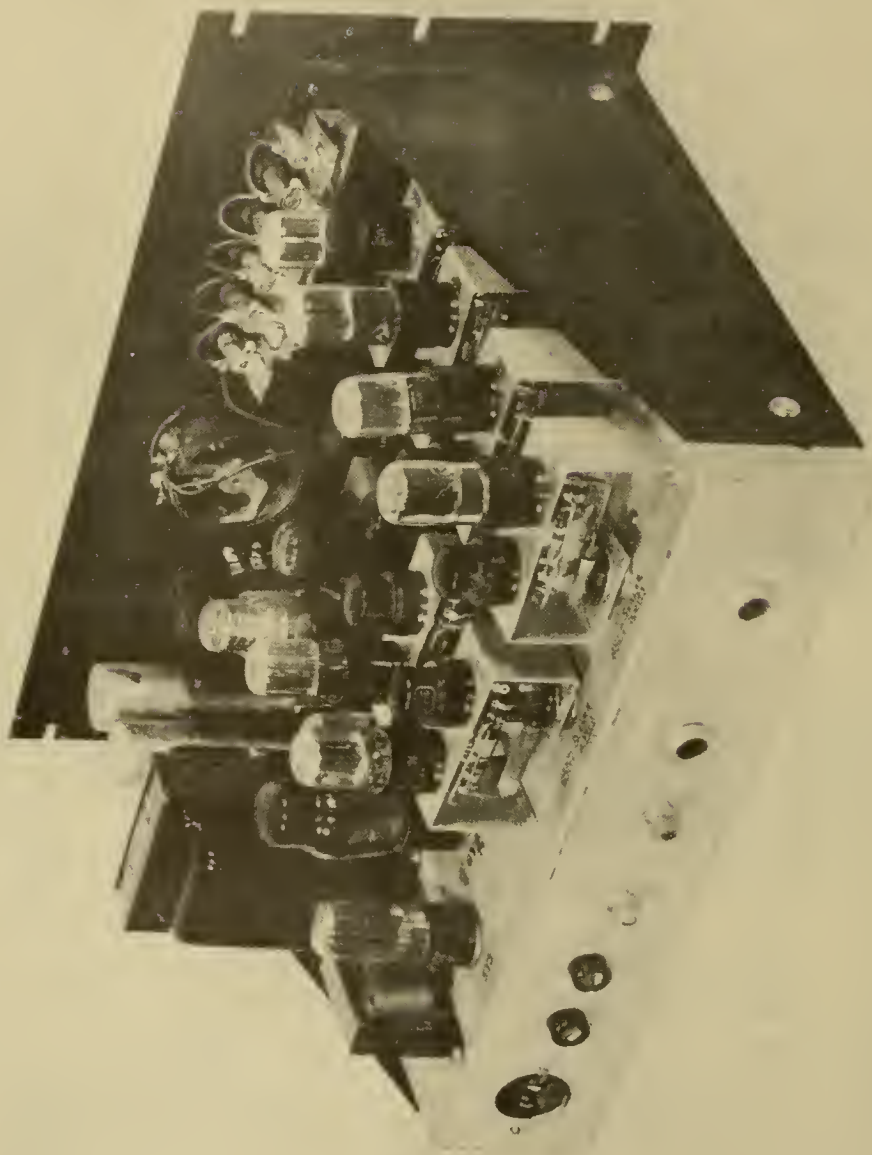

Figure 8. Photograph of the completed counter showing the plug-in scale-of-2.

appears at this point has a shape suitable for operating a very simple meter, which can be used for checking bias curves or operating conditions with given discriminator settings. The output of the sixth scaling stage is coupled directly to the register circuit described above.

Since a constant plate supply potential is needed for the discriminator, it is nearly as economical and somewhat more reliable to operate the complete counter from a stabilized plate supply. The supply shown in Figure 7 is of the degenerative type. This supply provides 55 milliamperes at 300 volts and an additional 5 milliamperes at 450 volts. The 300-volt supply is stable for input line voltages from 95 to 135 volts. It has a stabilization factor[10] of 700, an output resistance of 2 ohms, and has less than 3 millivolts of 120 cycle per second ripple at its output.

Several Model 200 Counters or their equivalent have been made and are in use at the Los Alamos Laboratory. Satisfactory operation has always been obtained. Failures which have occurred are usually due to either: (1) poor mechanical construction in the scaler units, i.e., bad solder joints, etc; (2) resistors which were more than 20 per cent outside of the rated values, particularly in the symmetric parts of the circuit (no trouble has been experienced when 5 per cent tolerance or matched resistors were used); (3) failures or extreme unbalance in tubes. All tubes are operated within rated dissipations and voltages, but, since such equipment is usually kept operating 24 hours a day, weak tubes soon show up. Many counters, however, have been operating for more than a year with no servicing.

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[10] Ratio of fractional change in input voltage to fractional change in output voltage.

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